GEORGIA TECH RESEARCH INSTITUTE

PROPOSAL: FEASIBILITY STUDY TO DETERMINE ECONOMIC AND OPERATIONAL BENEFITS OF UAVS IN SUPPORT OF GDOT OPERATIONS

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ESTIMATED COST: $75,000

TIME TO COMPLETE: 12 MONTHS FROM PROJECT INITIATION

PROPOSAL: UAV (Unmanned Aerial Vehicle) APPLICATIONS IN GDOT OPERATIONS

FEASIBILITY STUDY TO DETERMINE ECONOMIC AND OPERATIONAL BENEFITS IN SUPPORT OF GDOT OPERATIONS

INTRODUCTION

Unmanned Aerial Vehicles (UAVs) are becoming more and more prominent across an array of operational environments. In February 2012, the US Congress mandated that the Federal Aviation Administration (FAA) establish six regional UAV test sites to collect UAV research and flight test data in support of developing policy and certification requirements for UAV integration into the National Airspace System (NAS) by 2015. The State of Georgia is actively seeking the establishment of one of the six test sites to be located in the state.

There are numerous challenges associated with integrating unmanned aircraft into the NAS. Current regulations allow unmanned aircraft to fly in either restricted airspace or in the NAS with a Certificate of Authorization (COA), the latter of which is determined on a case-by-case basis. To develop sound policies that alleviate these restricted operations of UAVs in the NAS, it is important for the FAA to collect as much relevant data as possible.

The proposed feasibility study will identify potential uses of UAVs across all GDOT divisions. It will detail user requirements, and it will present a cost benefit analysis. The study will analyze the operations of each division within the Department to determine the potential missions that may involve UAVs, and it will identify UAV design characteristics to support meeting requirements associated with these missions. A cost benefit analysis will be conducted for each identified division to determine if UAV utilization is both operationally and economically viable. Data collection and analyses from past studies and from existing and ongoing research for each UAV application will be leveraged to support both technical and financial assessments.

The ultimate goal of this study is to provide a starting point for the development and flight testing of UAV for Departmental applications that help the Department attain its goals more efficiently and economically. It will also enable the State of Georgia to provide pertinent UAV data to the FAA to help guide policy development and decision making.

The use of UAVs has the potential to support the GDOT in many of their current operations, including monitoring and controlling traffic on surface streets during and after emergency incidents, monitoring bridges and overpasses during severe weather or general maintenance, day-to-day monitoring of roadways for preventative maintenance activities, and managing work zone and traffic congestion while enhancing the safety of workers.

The proposed effort will identify potential benefits of UAV operations, including lower operational costs, reduced maintenance, and increased flexibility. Additionally, traditional aircraft are often difficult to mobilize in emergency conditions so that UAVs may offer an improved rapid response capability.

These anticipated benefits, coupled with preliminary research in the feasibility of using UAVs in meeting State transportation department needs (Barfuss, 2012) (Brecher, Noronha, & Herold, 2003) (Latchman, Srinivasan,

Shea, Wong, & McNair, 2005) are encouraging. This past research will be leveraged as a starting point for the proposed study.

Additional use cases will be examined for cost benefits analysis. Specifically, Washington State considered UAVs for snow avalanche control (McCormack, 2008) and identified operational advantages. This was in addition to data and image capture for traffic surveillance. Although they encountered FAA restrictions, they determined these restrictions could be overcome once the new FAA regulations were established. Another study by Gu (Gu, 2009) examined the use of small, Remotely-Controlled aircraft for transportation use and found that data acquired with such platforms could support work zone and congestion management and environmental monitoring The monitoring of unpaved rural roads was identified as an application that is ideally suited for the application of UAVs (Zhang).

There are documented challenges to be overcome with flying UAVs in the NAS (Kapseong, Oh, & Liang, 2007) this group encountered substantial problems with regard to getting the necessary approvals and permissions to operate their vehicle. GTRI has significant experience and detailed knowledge of procedures to obtain Certificates of Authorization (COAs). Specifically, GTRI has more COA applications than the University of North Dakota, one of the benchmark universities doing UAS research. This experience will be used to inform the proposed research study.

GTRI RELATED WORK AND RESOURCES

The Georgia Tech Research Institute (GTRI) is a recognized leader in innovative and advanced research for unmanned systems, spanning from basic research to advanced prototypes and test and evaluation. In addition GTRI has many years of experience working with the GDOT and has an extensive understanding of the many operations conducted by GDOT.

GTRI conducts contract research to support its various customers in the development, prototyping, and testing of systems to address their challenges. Two examples of past GDOT work that lend themselves to use of UAVs include (i) Fog/visibility monitoring, where results indicated that for low visibility events due to fog or smoke, more localized information on conditions can support decision making and management of the events. Such data could be readily provided by a UAV; (ii) SmartPhone for sensing, which demonstrated the possibility of identifying segments of roadways that deviated from other segments. UAVs could be one approach to evaluating the causes of the deviations.

Core competencies in UAV research include: (i) Autonomy and Collaborative Control, which encompasses payloads and sensor processing (2D and 3D image processing; various sensor modes IR, RADAR, LIDAR, etc.); intelligent autonomous control, including integrated learning algorithms and path planning; advances in system control, including low-level control and mechanical control; intuitive motion control; mission planning; and JAUS and STANAG-4586 compliance, (ii) Hardware Systems Development and Testing, which encompasses platform-development for unmanned air, ground, and undersea vehicles; micro-air vehicles; aircraft modeling and flight simulation; innovative noise reduction methods; computer architectures and embedded processing; and flight testing (Certificates of Authorization granted), and (iii) Testing and Evaluation, which encompasses simulation and flight, ground, and sea testing. One example capability is GTRI's fleet of quarter-scale Piper Cub UAVs that contain autopilots and on-board image processing (Figure 1). Sony KX191 CCD cameras are used to stream video and uEye UI-2230SE cameras with 1024×768 are used to capture for high resolution still frame images.

Figure 1 - GTRI's fleet of quarter-scale Piper Cub UAVs (left) and their onboard electronics (right)

As a second example, for the Centers for Disease Control, GTRI developed a lightweight automated still frame imaging system for use on UAVs, called the Modular Photographic Observation Device (ModPOD). This system was developed to take and store GPS-registered, high resolution images using a 10 mega-pixel commercial camera (Figure 2). The processing behind this system constructs high resolution mosaic images (Figure 3).

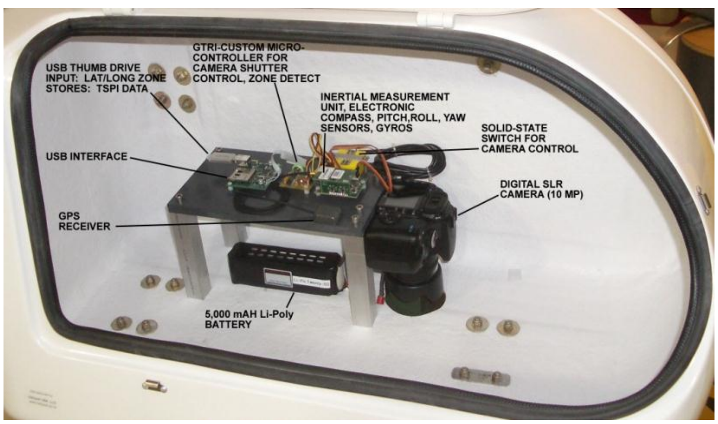

Figure 2 - GTRI ModPOD

Figure 3- Mosaic Image from GTRI's ModPOD

Additional capabilities are presented in Appendix A.

OBJECTIVES

The objectives of this proposal are to conduct a study that provides specific information to GDOT on the requirements and utility of using UAVs in its operations and missions. Specifically, this effort will

1. Determine the potential uses for UAVs across all GDOT divisions
2. Detail the user requirements for UAVs across all divisions
3. Identify UAV related technologies to support those requirements
4. Conduct a cost-benefit analysis for each identified UAV application
5. Provide a summary of ongoing research activity in each UAV application area

These objectives will then support the broader GDOT needs of

1. Providing the GDOT with technologies to advance the safety, efficiency, and capacity of the state transportation system, and

2. Promoting research and flight data collection to support the FAA in developing policies and certification requirements for UAV integration in the National Airspace System

WORK PLAN

This effort will provide the GDOT with the results of a study to support GDOT use of UAVs in their various operations and missions. The following tasks will be executed to achieve the specific objectives.

1. Conduct Literature Review
2. Survey GDOT Divisions
3. Identify Potential Applications
4. Develop UAV Specifications aligned With Applications
5. Identify Technologies to Support Applications
6. Develop User Requirements
7. Conduct Cost Benefit Analysis
8. Prepare and Present Final Report

The final report will include: findings from the literature review, a description of potential applications for GDOT divisions, UAV specifications aligned with these applications, user requirements; technologies that are available and potential applications of those technologies in meeting the requirements, and an economic and operational analysis of utilizing UAVs in supporting GDOT needs..

A Gantt chart for the execution of the project is shown in Figure 4.

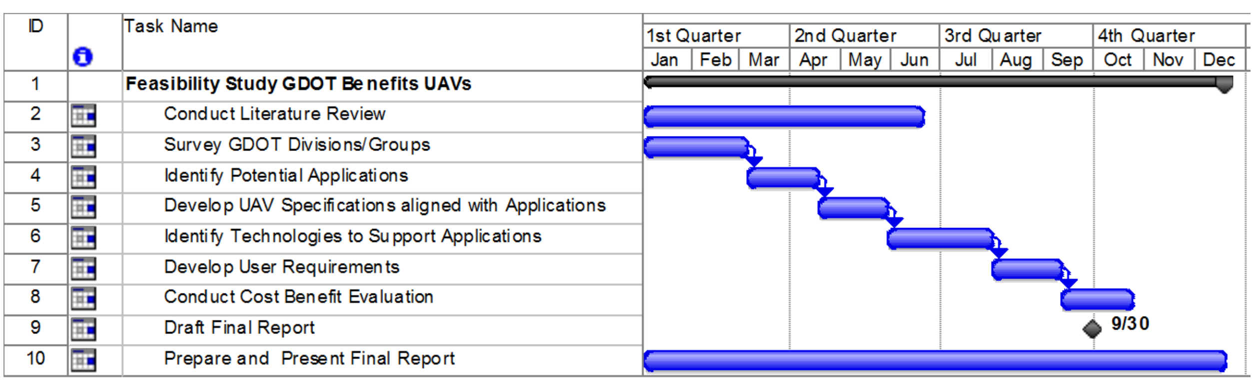

Figure 4 - Gantt chart showing timeline for execution

The activities to be conducted for each task are detailed below:

LITERATURE REVIEW

A comprehensive literature review and survey will be conducted to understand the existing state of UAV technology to support DOT applications. This literature review will help guide the development of the survey

for identifying specific GDOT applications. This will be an ongoing effort as the team identifies activities underway in other state DOTs.

SURVEY GDOT DIVISIONS

GTRI will conduct a survey of all GDOT divisions to determine functions that could be supported by UAVs. This will be done by constructing a survey website through the Georgia Tech virtual hosting system using a PHP-based survey package (e.g., LimeSurvey). The survey will be designed to collect information needed to define the possible applications of UAVs to support GDOT missions and operations. The results of the survey will be analyzed and follow up interviews will be conducted to ascertain details of specific applications and to address questions that arise from the survey. The result of this effort will be the development of descriptions and specifications for the different UAV applications deemed to be of interest to GDOT.

IDENTIFY POTENTIAL APPLICATIONS

Based on the results of the survey, GTRI working with GDOT, will identify applications that could be of benefit to GDOT, that could be conducted with UAVs, and that have a high probability of success. Those applications that are able to support operations in more than one division would rate higher for first generation implementation over single department solutions. An example of the type of data to be collected is presented in Table 1.

Table 1 Application Description

Task Description	Inspection of Bridge
Data Required	High resolution image and accelerometer readings
Day/Night Operation	Day only
Altitude	Greater than 1000 feet
All Weather	No inclement weather
Rural/Urban Area	Rural Areas
Operations to be augmented	Visual assessment by two people each year
Other Departments	Maintenance and Planning

DEVELOP UAV SPECIFICATIONS ALIGNED WITH APPLICATIONS

The specifications for conducting the different applications identified in the preceding task will be delineated. Table 1 will be augmented to identify the UAV platform requirements and sensing specifications. This will then be incorporated into the performance parameters for the airframe and its subsystems.

TECHNOLOGY APPLICATION AND IDENTIFICATION

Once the applications are detailed and the UAV specifications are defined, the technologies best suited to addressing the applications will then be identified. This will include identifying the sensing systems, airframes, and control systems suitable for achieving the desired functionality. This information will then be used in the cost/benefit analysis.

DEVELOP USER REQUIREMENTS

After the recommended airframe(s) and supporting technologies are identified that will support the selected application(s); the requirements for training, operation and maintenance of the chosen UAV assets as required by the different divisions/offices will be generated. This step will also provide data that will be used in conducting the cost benefit analysis.

COST BENEFIT ANALYSIS

Once the UAV applications, airframes, and sensors have been identified a cost analysis will be conducted by identifying the direct and indirect costs. Direct costs include the initial capital required to procure a UAV system as well as operating, maintenance, training, certification of personnel, and other support costs associated with the UAV missions. Indirect costs such as insurance and storage will be identified. Both direct and indirect costs will vary by the types of UAV applications and the types of sensors identified.

The analysis will then look at the benefits associated with the specified UAV applications. Cost information obtained from GDOT for processes and procedures will be compared to costs associated with UAV operations to perform the same missions, both for the short term and the long term. Finally, tools such as return on investment, breakeven, and payback periods will be presented in a matrix to quantify and compare the various UAV applications.

REPORTING

The deliverable for this project will be a report outlining the options available to the GDOT to address the different potential applications that were identified, with a recommended path forward. A draft report will be generated three months before the end of the contract for GDOT review.

OTHER CONSIDERATIONS

In the operation of UAVs several aspects must be considered, including the ability to obtain authorization to fly as well the planning of the flight operations. GTRI has a broad and deep knowledge of the expanse of these considerations, some of which are described below.

REGULATIONS/CONSIDERATIONS THAT GOVERN UAV OPERATION

In response to the growing need to integrate UAVs into the National Airspace System, in February 2012, Congress directed the FAA to establish six regional UAV test sites within the continental United States. Georgia is seeking to be a location for one of the UAV test sites. The Georgia UAV Airspace Integration Team (GUAIT), which is a collaboration of academia, government, industry, Georgia National Guard, and Law Enforcement, is working toward the establishment of Georgia as one of six UAV test sites. To support the GUAIT effort, GTRI is establishing several purpose-specific Certificates of Authorization throughout the

State of Georgia which afford the opportunity to fly various types of UAVs over a variety of terrain in Georgia. Work conducted at these sites, irrespective of becoming one of the six FAA test sites, can benefit GDOT by demonstrating the utility of UAVs to accomplish their missions. Participation in one of the test sites would position Georgia as a leader in testing and evaluation of these evolving UAV applications and provides an efficient path to deployment for GDOT. The GDOT could readily be included as a partner in GUAIT.

AIRSPACE REGULATIONS

Even without GUAIT, GTRI is experienced and versed in the procedures for obtaining COAs (Certificate of Authorization) to operate UAVs. Except for restricted airspace on military bases (e.g., Ft. Stewart near Savannah, Ft. Benning in Columbus), all air space in the United States is part of the National Airspace System (NAS). The NAS is under the authority of the Federal Aviation Administration (FAA). Protecting and ensuring the safety of air travel and aircraft are the primary responsibilities of the FAA. Their rules and regulations for UAVs are similar to those for manned aircraft. Pilots and crew members of a UAV must have a similar licenses and medical certificates as pilots and crew of manned aircraft have. UAV pilots and crew must also maintain currency (90 days) with each aircraft.

For GDOT to operate a UAV in the national airspace, GDOT or GTRI would need to obtain a Certificate of Authorization from the FAA. The COA is granted for a single UAV platform at a specific geographical location and is valid for up to two years. The requirement for a COA has a significant impact on the ability to operate UAVs in Georgia. Currently, only public entities such as state and federal agencies and universities may receive a COA. However, both GDOT and GTRI qualify as public entities. GTRI has extensive experience in obtaining COAs and in operating UAVs in the National Airspace System. At this time, GTRI has six active COAs, with an additional five under consideration and eleven in progress. These are for flight operations at several locations across Georgia. The process of obtaining a COA is detailed in Appendix D.

UAS OPERATION ISSUES

There are several other issues that one must be aware of regarding the operation of UAVs, including: regulatory, security, safety, liability, privacy, civil rights, right of way, property access for over flight, and flights over national parks, forests, or wildlife refuges. Noise abatement may be an issue with larger UAVs that are powered by internal combustion engines. This is less of an issue for smaller, electric-powered motors.

The issue of safety and liability can be addressed by maintaining safe operational procedures for both the UAV and the flight crew. As part of every flight operation, GTRI uses strict safety procedures. Not only is a risk management plan enforced, but also extensive pre-flight checklists and maintenance procedures are followed. Operations and maintenance details are noted in a logbook for each UAV and each flight.

Insurance coverage and liability are important to any UAV project being planned. The State of Georgia and GTRI are self-insured, but consulting the appropriate departments while planning a UAV project is prudent to verify all liability aspects of the project.

Recently there has been increased concern by the public for privacy and civil rights that may be affected by agencies using UAVs. The principal technical organization for unmanned systems, the Association of Unmanned Vehicle Systems, International (AUVSI), responded to this public concern by issuing a Code of Ethics for UAVs and other unmanned systems. Among the topics address by this Code is the need to maintain an individual's privacy. This may be accomplished by using sensors and the resulting data such that facial features of the individual are not recognizable. Law enforcement agencies must also abide by certain privacy and legal regulations. These include, in some cases, requirements for a court order prior to the use of

a UAV to obtain imagery of an individual. While not likely an issue with GDOT programs, it is a concern that GTRI is capable of mitigating satisfactorily.

MISSION PLANNING WITH FALCONVIEW

While not needed for the initial study, the generation of mission plans or of a sequence of operations to efficiently conduct the various missions will be important as GDOT integrates UAVs into their toolsets. FalconView is an open source mission planning, situational awareness, and GIS application created by the Georgia Tech Research Institute for the Windows family of operating systems that has over 80,000 users. It displays most common map types and geographically referenced overlays, including aeronautical charts, satellite images, and elevation maps. FalconView also supports a large number of overlay types that can be displayed over any map background.

FalconView is widely used for aviation mission planning, analysis, execution, and after action review. The current user bases consists of users in the U.S. Department of Defense, the FAA, the Department of Homeland Security, other Federal agencies, military partner nations, and the open source community.

FalconView has also been integrated into multiple unmanned and autonomous systems control stations, including the MQ-1 Predator, Raven, and Shadow. Following are example scenarios in which FalconView can be used as part of UAV operations:

1. **Mission Planning** – FalconView provides a framework for route definition, flight planning, and collaboration during the mission planning stages. Multiple maps and overlays can be imported to assist with flight planning. Overlays include elevation profiles, no-fly zones, and flight hazards.
2. **Mission Execution** – FalconView can display to the user an operational picture showing the location of UAVs through a moving map display or customized application plugin.
3. **UAV Imagery** - UAV imagery can be processed offline, using image-processing tools (*outside of FalconView*) to stitch and geo-rectify new imagery gathered from a UAV. This imagery can then be loaded into FalconView for up-to-date mission planning.
4. **Sensor Overlays** – through the use of custom application plugins, output from sensors can be displayed on the map and available to the flight operations crew in real-time.

FalconView's robust set of application interfaces allow third party developers to create application plugins and to fuse their information into a single coherent picture of the user's area of interest. Sample imagery from FalconView is shown in Figure 5. A more detailed description of FalconView and its application is presented in the Appendix C.

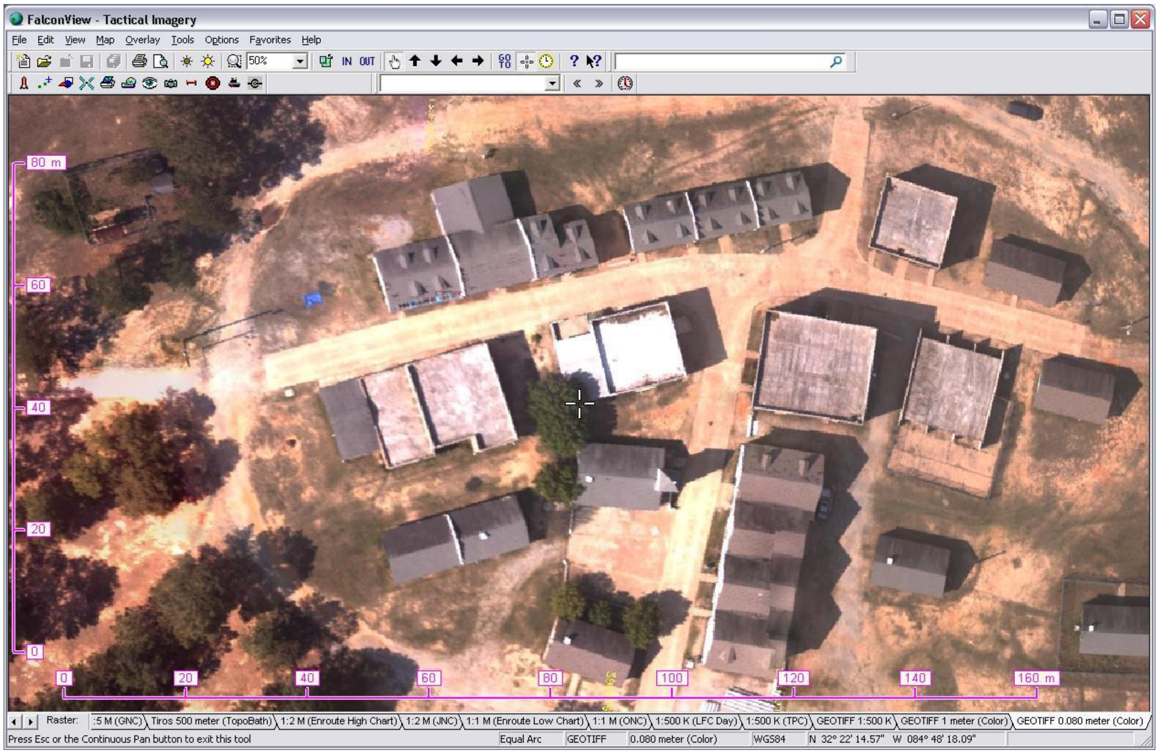

Figure 5 - UAV Imagery Stitched and Uploaded into FalconView

SIGNIFICANCE OF RESEARCH

As the GDOT continues to seek improvements in effectiveness and cost efficiencies in supporting the transportation infrastructure, the utilization of UAVs in support of operations and missions must be considered. The research proposed will provide the GDOT with information on potential benefits, user requirements, and costs associated with operating UAVs to meet the needs of the different divisions and offices in the GDOT. The US Department of Defense (DoD) has documented evidence of how UAVs effectively and efficiently conduct missions associated with the three Ds: the dull, the dirty, and the dangerous. GDOT will likely benefit in a multitude of applications, just as DoD has. Technology advances in unmanned systems are progressing on almost a daily basis. The potential exists for GDOT to not only improve efficiency, but to also ensure the safety of personnel tasked with conducting many of the operations and missions that require them to be on or near the roadway or in remote locations.

SUMMARY OF DELIVERABLES

The main deliverable will be a report containing: findings from the literature review, a description of potential applications for GDOT divisions, UAV specifications aligned with these applications, user requirements; technologies that are available and potential applications of those technologies in meeting the requirements, and an economic and operational analysis of utilizing UAVs. The report will support the next phase: design,

development, research, and testing the UAVs demonstrating their potential benefit in supporting GDOT operations.

IMPLEMENTATION PLAN

The results of the findings in this study will support GDOT in its next phase of developing of a larger a plan for the design, development, research, and testing of UAVs which are identified as beneficial to the Georgia Department of transportation.

BUDGET ESTIMATES

The estimates created according to the rules and guidelines of Georgia Tech are presented below.

BUDGET TOTAL

The budget estimate for the total project is: $75,000.

TOTAL BUDGET SUMMARY

Please find the detailed budget and summary in the attached cost proposal.

WORK PLAN SCHEDULE

This project is a 12 month effort. The schedule by which this will be accomplished is presented in the Gantt chart shown in Figure 4.

COOPERATIVE FEATURES

Georgia Tech will work with the appointed personnel in GDOT research and the various divisions in conducting the surveys and summary of needs and specifications.

SUPPORTING FEATURES

GDOT will work with Georgia Tech in providing access to the necessary personnel, sites, and operations

REFERENCES

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APPENDIX

APPENDIX A – GTRI CAPABILITIES

GTRI specializes in UAV integration, rapid product development, and prototyping. The lab has a dedicated facility (Figure 6) for UAV construction that supports machining, composites layup, electronics integration, 3-D printing, and vehicle assembly. The facility's 3-D printer has been used to rapidly prototype test article components for wind tunnel testing as well as electronic component racks for GTRI's unmanned aircraft. Other rapid product developments include a launching system and a recovery net to support UAS flight activities.

The ATAS lab has several unique facilities dedicated to aerospace research. These facilities include wind tunnels, anechoic chambers, high speed flow tunnels, and a fuel cell and battery lab. In a research program, sponsored by NASA, GTRI is conducting acoustic testing of small scale propellers in our freestream anechoic tunnel. Acoustic data from these tests will be used to validate NASA's propeller noise prediction models.

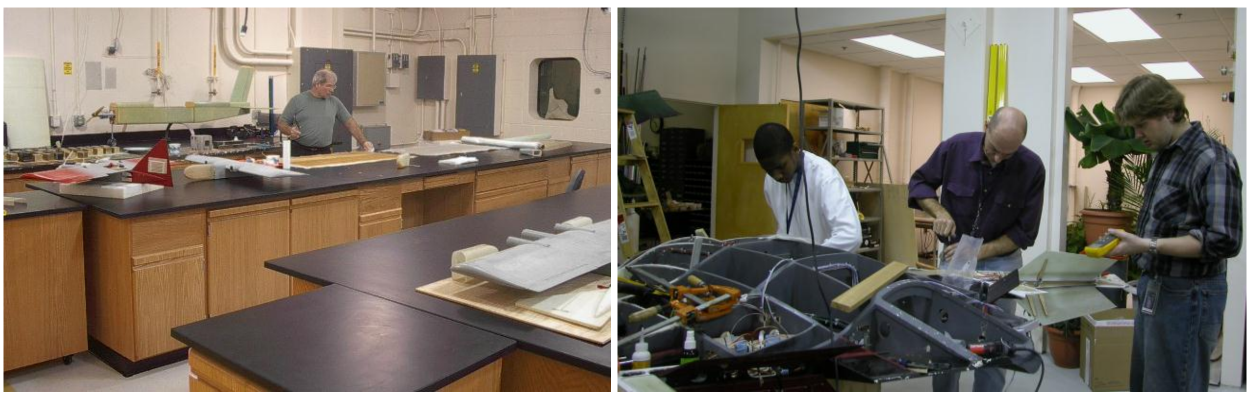

Figure 6- GTRI's UAV Lab Facility

GTRI has extensive experience in developing, modifying, and operating unmanned aircraft systems. In addition to an Outlaw ER (described in Table 2) and the CropCam (described in Table 3) our current fleet of aircraft includes the following types:

Table 2. Large Fixed Wing UAVs

			
Aircraft	ScanEagle	Outlaw ER	T-20
Manufacturer	Boeing	Griffon Aerospace	Arcturus UAV
Wing span	10 ft	16 ft	17 ft
Takeoff Weight	44 lb	150 lb	165 lb
Max. Endurance	24+ hrs	8-10 hrs	>18 hrs

Max. Speed	80 kt	75 kt	90 kt

Table 3. Small Fixed Wing UAVs

		
Aircraft	CropCam	Raven B
Manufacturer	CropCam	Aerovironment
Wing span	8 ft	4.6 ft
Takeoff Weight	6 lb	4.2 lb
Max. Endurance	55 mins	1 – 1.5 hrs
Max speed	35 kt	30 kt

Table 4. Quarter-scale Piper Cub

PARAMETER	VALUE
WING SPAN	8.8 FT
GROSS TAKEOFF WEIGHT	23 LB
OPERATING ALTITUDE	<1,000 FT
MAX. ENDURANCE	1 – 1.5 HRS
CRUISE SPEED	35-50 KT

Table 5. T-Rex 600/A

PARAMETER	VALUE
GROSS TAKEOFF WEIGHT	6 LB
ROTOR DIAMETER	3.5 FT
MAX. ENDURANCE	20 MIN

Table 6. QAV500 Quadrotor

PARAMETER	VALUE
GROSS TAKEOFF WEIGHT	4.2 LB
ROTOR DIAMETER	10 IN
MAX. ENDURANCE	20 MIN

Table 7. AR100 Quadrotor

PARAMETER	VALUE
GROSS TAKEOFF WEIGHT	2 LB
ROTOR DIAMETER	16 IN
MAX. ENDURANCE	20 MIN

Another great example of GTRIs experience with UAVs is related to work performed on the GTRI Airborne Unmanned Sensor System or GAUSS. On GAUSS, GTRI is working closely with a proven UAV supplier, Griffon Aerospace, located in Huntsville, Alabama. In this collaborative effort, GTRI has procured two Outlaw UAVs and is collaborating with the supplier to integrate a large payload of electronics shown in Figure 7. The unmanned aircraft system will have capabilities covering autonomous control, reconfigurable sensors (LIDAR, Chem-Bio, etc.), on board data recording, and multi-platform distributed sensor experiments.

Figure 7 - Griffon Aerospace UAV used on the GTRI GAUSS program.

APPENDIX B – UAV APPLICATIONS CUSTD

GTRI's Collaborative Unmanned Systems Technology Demonstrator (CUSTD) program involved multiple UAVs and a UGV working together in a collaborative, autonomous team (Figure 8). The research platform consists of multiple, tactical UAVs that perform on board computer vision tasks and run autonomous behaviors. The UGV performs waypoint navigation and obstacle avoidance over a road network. The vehicles all operate autonomously and can exchange mission messages with each other using the JAUS standard. The vehicles perform air to ground teaming in a target detection and surveillance mission as well as distributed task allocation using market-based technologies.

In a directed cooperation mission, multiple aerial vehicles search for a target and once it is found, direct ground vehicles and other air vehicles to the target location to perform autonomous surveillance. This platform is part of our ongoing commitment to Unmanned Systems research at GTRI and can be used both internally and in externally sponsored research to study improvements to Unmanned Systems sensors, operations, and collaborative autonomy.

The CUSTD program also serves as a research platform for demonstrating autonomous task assignment using market-based algorithms. Ongoing work includes the ability for heterogeneous vehicles (vehicles with different capabilities and different sensor characteristics) to collaborate on a shared mission to distribute tasks in dynamic and decentralized manner. In domains where there are a large number of tasks to be shared between a large number of vehicles with different characteristics, it will be important for vehicles to work together in a distributed and dynamic way to allocate tasks amongst themselves without (or perhaps in addition to) human direction.

Figure 8 - UAVs and a UGV working together collaboratively

APPENDIX C – UAV MISSION PLANNING WITH FALCONVIEW

FalconView is a mission planning, situational awareness and GIS application created by the Georgia Tech Research Institute for the Windows family of operating systems. It displays most common map types and geographically referenced overlays, including aeronautical charts, satellite images and elevation maps. FalconView also supports a large number of overlay types that can be displayed over any map background. FalconView is widely used for aviation mission planning, analysis, execution, and after action review. The current user bases consists of over 80,000 users in the U.S. Department of Defense, the FAA, the Department of Homeland Security, other Federal agencies, military partner nations and the open source community.

FalconView has also been integrated into multiple unmanned and autonomous systems (UAS) control stations, including the MQ-1 Predator, Raven, and Shadow. Following are example scenarios in which FalconView can be used as part of a UAS:

1. **Mission Planning** – FalconView provides a framework for route definition, flight planning and collaboration during the mission planning stages. Multiple maps and overlays can be imported to assist with flight planning. Overlays include elevation profiles, no-fly zones, and flight hazards.
2. **Mission Execution** – FalconView can display to the user an operational picture showing the location of UAVs through a moving map display or customized application plugin.
3. **UAV Imagery** - UAV imagery can be processed offline, using image-processing tools (*outside of FalconView*) to stitch and geo-rectify new imagery gathered from a UAV. This imagery can then be loaded into FalconView for up-to-date mission planning.
4. **Sensor Overlays** – through the use of custom application plugins, output from sensors can be displayed on the map and available to the flight operations crew in real-time.

FalconView's robust set of APIs allow diverse third party applications develop application plugins and to fuse their information into a single coherent picture of the user's area of interest. The users know that data produced on FalconView is interoperable and can be shared with partners. FalconView can also be included as part of an operations center and allow for collaboration between multiple users across a network.

UAV CASE STUDY

GTRI has developed an Unmanned Aerial Vehicle (UAV) demonstrator platform for performing research in autonomous UAV cooperation. The system consists of multiple Unmanned Aerial Vehicles (UAVs) that can operate autonomously and accept missions from a ground station. The system communicates and the vehicles collaborate with each other in a distributed manner. The vehicles in this system communicate to FalconView to display vehicle position and telemetry information in real time. The ground station can also be used to send messages to the vehicles and to send other waypoint and mission based commands. As the vehicles in the system perform the mission, the vehicles' behavioral states are displayed over the FalconView maps, along with the vehicle positions. Detected target locations are updated on the map as well. Geo-rectified images can also be imported into FalconView as up to date imagery of the mission area.

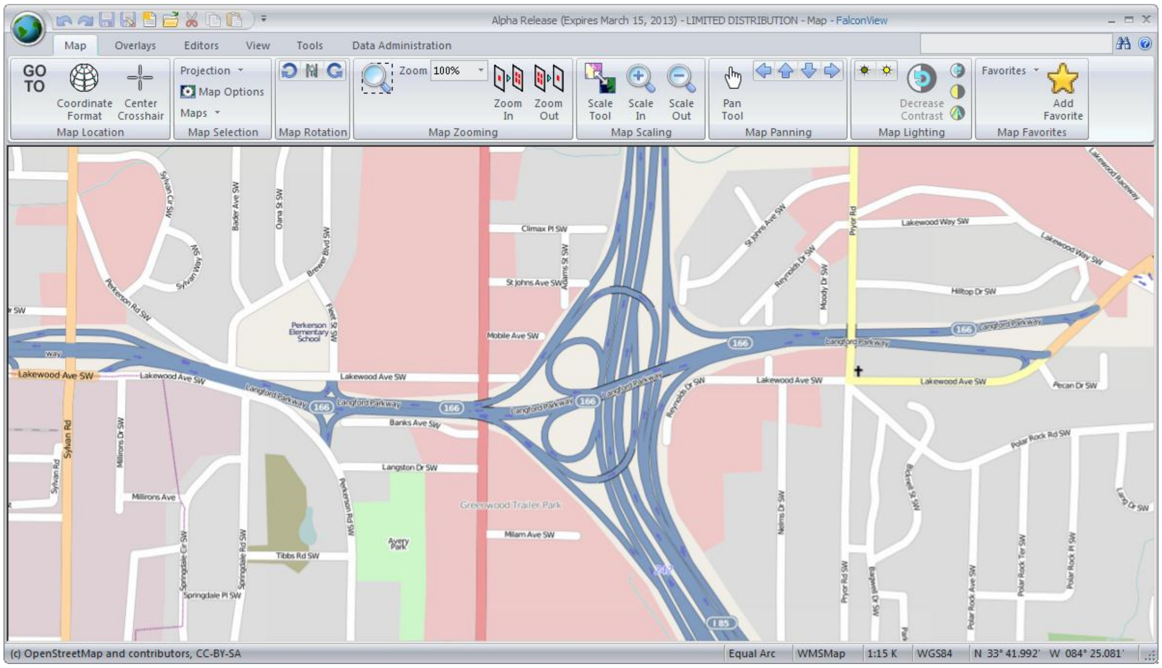

Figure 9 - FalconView Map Display

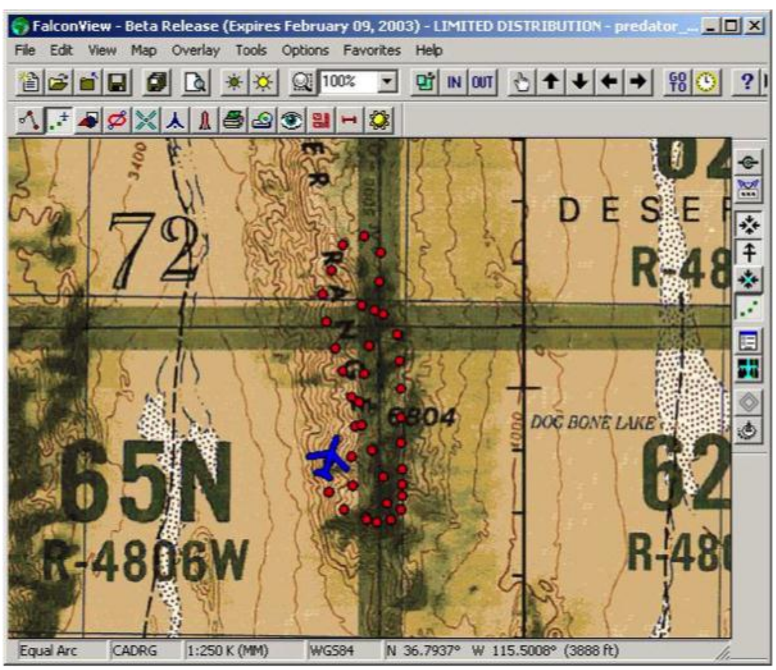

Figure 10 – Predator UAV Feed Display

Figure 11 - UAV Custom Plugin

Figure 12 - Imagery Gathered from a UAV

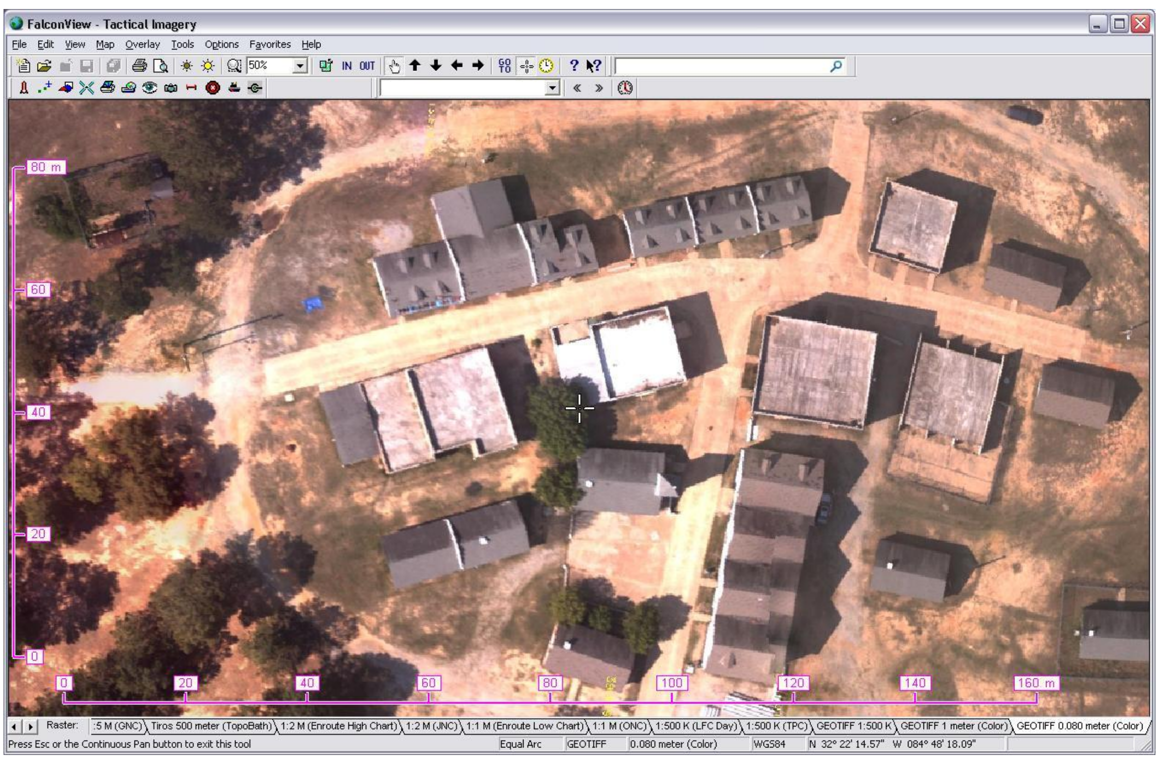

Figure 13 - UAV Imagery Stitched and Uploaded into FalconView

APPENDIX D – PROCESS FOR OBTAINING A COA (CERTIFICATE OF AUTHORIZATION)

To apply for a COA to conduct UAV flights for GDOT projects, the steps below would be a typical work flow for a project.

1. Identify the project goals and select the appropriate sensor and UAV platform (rotary wing for slower speed or hovering flight and close up inspection vs. fixed wing for higher speeds to cover longer distances or more area during a single flight).
2. Determine UAV performance and control system specifications. These are required to provide the necessary documentation for the FAA to approve a COA. These technical documents describe items such as lost link behavior and other possible failure modes that would affect UAV safety and performance.
3. Estimate the duration of the project along with the starting and ending dates to align COA award with operational dates.
4. Determine the location at which the UAV will be operated during the project.
5. Select a pilot and flight crew for the project duration and ensure their availability to support the project both in time and UAV qualifications.
6. Outline the boundaries of the air space necessary and evaluate the feasibility with regard to anticipated FAA safety concerns such as altitude, nearness to public airports, or populated areas.
7. Prepare a COA application with documents addressing the necessary areas based on the above details. Some of these items include.
    a. Lost Link procedures must satisfy FAA that UAV will not fly into occupied airspace. Requires detailed explanation of control behavior if signal is lost, how the pilot will handle situation, and communications with Air Route Traffic Control Center (ARTCC).
    b. Airspace details: Must be outside Mode "C" veil, must avoid Air Routes, Military Training Routes, Populated Areas, Altitude Limits, and National Forests.
    c. Request airspace boundaries in detail with maps, Lat/Long, altitudes, speeds, and description of how to mitigate confliction with other aircraft.
    d. Description of how UAV will remain in visual contact, e.g., use of a chase plane or observers down range.
    e. Details of radio control, sensors, radio frequencies, devices and if approved by FCC via license or waiver.
    f. Details of radio communications equipment for contacting Air Traffic Control Center before/during/after flight.
    g. Details of flight performance recording.
    h. Monthly reporting of each flight and any incidents (lost link, comms, or accidents).